Special Session on

MILITARY APPLICATIONS

Anti-monopulse Jamming Techniques

Dr. Filippo Neri

Anti-Monopulse Jamming Techniques

DR. FILIPPO NERI
ELETTRONICA S.P.A. - ITALY

INTRODUCTION

Modern radar systems make use of new advanced radar techniques (e.g. pulse compression, frequency agility/diversity, monopulse angles tracking, etc.) and effective ECCMs (e.g. ant-range gate stealing (ARGS), Guard Gates, etc.) that reduce significantly the effectiveness of EW countermeasures.
Even if some advanced EW technologies, like Digital Radio Frequency Memory (DRFM) and very fast digital processing, are capable of countering coded radars and pulse doppler radars, the combination of radar ECCM and radar techniques still represent a serious problem to EW effectiveness.

For instance, monopulse radars operating in frequency agility mode and exploiting Anti Range Gate Stealing (ARGS) ECCM technique are presently difficult threats to be jammed.

In fact the frequency agility mode forces the jammer to select deception jamming techniques only (since noise jamming techniques, forced by the frequency agility to spread the power over a very wide RF bandwidth, are not effective). On the other side, the deception jamming technique, such as RGPO, is, as well, not effective since it is defeated by the Anti Range Gate Stealing counter-countermeasure.

The solution of this dilemma is that ECM Systems have to exploit techniques capable of defeating monopulse radar in a "direct mode", preventing them from performing accurate angle tracking.

ANTI-MONOPULSE JAMMING TECHNIQUES

So far, several anti monopulse advanced jamming techniques have been proposed: some of them have just been studied, some have been tested and some are already in operation.
The following presents a general overview of the most commonly known anti-monopulse jamming techniques such as:
- Cross Polarisation;
- Towed Decoy;
- Expendable Decoy;
- Wavefront Distortion (WFD), i.e. Cross-Eye Jamming (CEJ).

underlining their benefits and drawbacks.

Cross Polarisation

The basic concept of the Cross Polarisation (Cross-Pol) ECM technique is that, in general, a tracking radar antenna presents, for a cross polarised signal, an "off-set" angular characteristics with respect to the nominal polarised signal (see Fig. 1), so that the tracking point (or equilibrium point) is achieved in a different position with respect to the antenna boresight.

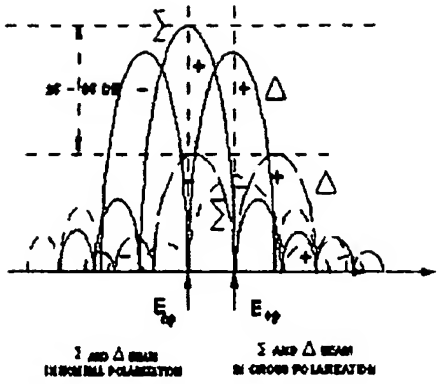

Fig. 1: Tracking antenna characteristics

The Cross Polarised signals are, of course, strongly attenuated by the Antenna Polarisation Purity Factor (PF).

If the ECM system can radiate a cross polarised signal of adequate power the tracking radar will then track the target with an angular offset (angular error).

Advantages.

The good points of Cross-Pol are represented by the fact that the angular error can be quite large (of the order of the radar beam-width), and it can be easily switched on and off, creating significant oscillations on the line of sight of the enemy weapon system.

Disadvantages.

The weak points of Cross-Pol jamming technique are mainly:

- Cross-Pol requires a very high J/S ratio since tracking radar antennas are designed to cancel or attenuate, by a large extent, the cross polarised signals. If enough jamming power is not available, then the RGPO is required first which, as explained before, may not be always effective.
- Cross-Pol produces an angular error and, consequently, is in principle not suitable against missile threats: in fact, since the miss distance is the product of the distance multiplied by the tangent of the angular error, when the distance is very short (incoming missile) the miss distance becomes negligible (see Fig. 2).

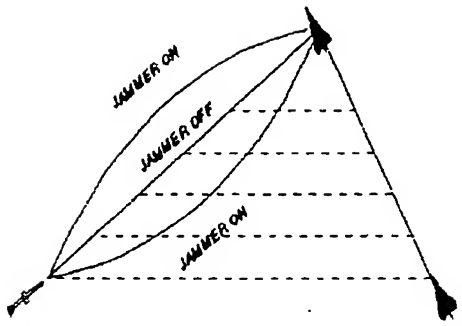

Fig. 2: Cross Pol effect on homing missiles

- Cross-Pol Jamming requires, to be effective and to compensate for the platform pitch and roll, an accurate measurement of the transmitted polarisation. In this way it is implemented what is known as the "Adaptive Cross Polarisation" Jamming. The implementation of this technique requires advanced technology. Of course, to be effective, it is necessary that the radar uses, when receiving, the same polarisation used in the transmitting mode.
- The "depolarisation" effect of sea or ground can alter the purity of the cross polarised jamming signals, and can generate components in the nominal polarisation, creating an unwanted "beaconing" effect.
- If the radar purity is high it becomes impossible to generate effective cross polarised signals (see Fig. 3).

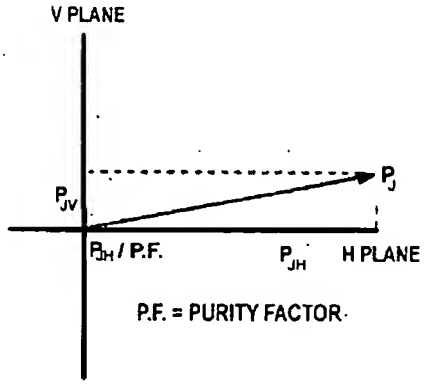

Fig. 3: Effect of radar polarisation purity

Towed Decoy

The basic idea of this jamming technique is quite simple: to use a small beaconing system installed in a pod, towed by the platform to be defended (see Fig. 4).

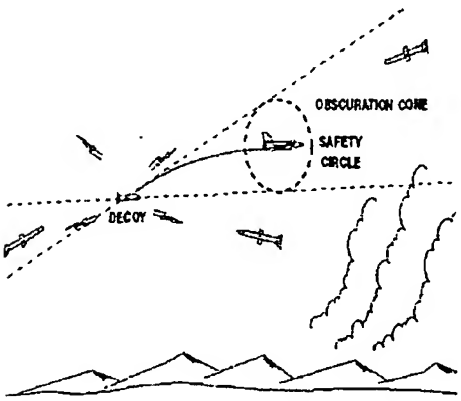

Fig. 4: Towed Decoy

Even if in principle this technique can be used both for ship and aircraft protection, products are mainly available only for the latter.

Advantages.

The main advantage of this technique is represented by its credibility. In fact, this technique is very easy to understand: everybody knows that a tracking radar can track a beacon as beaconing systems are normally used to test and verify radar performances!

Disadvantages.

There are several disadvantages that are normally overlooked.

Seduction capability: even if it is easy to demonstrate that a radar can track a beacon system, it is not clear how it is possible to convince a good radar equipped with ECCM and locked onto a target to switch from target tracking to beacon tracking.

Seduction through generation of noise jamming signal, so that the radar will start "track-on jam" mode, could be rather difficult. In fact, considering again the above mentioned monopulse radar in frequency agility mode with ARGS countermeasure, it appears clearly that wide bandwidth noise jamming is not effective, (therefore no track on jam mode will be started) and the beacon signal is too delayed with respect to the range gates to be taken into consideration by the radar (see Fig. 5).

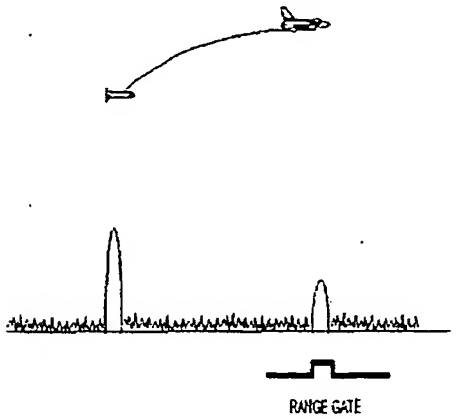

Fig. 5: Deceiving signals out of range gates

Therefore it appears that only CW or PD radars with very poor range discrimination could be seduced by a Towed Decoy.

- Obscuration cone: from geometrical considerations is it possible to identify two cone sectors (obscuration cones, Front and Rear) where Towed Decoy protection is not assured. Unfortunately these cones are located in sectors where the probability of attack is quite high.

Some Towed Decoy manufacturers suggest that the pilot should implement a turning manoeuvre to reduce the effect of the blind cone. Beside the fact that doing so the platform RCS will increse significantly (reducing the available Jamming to Signal Ratio!), the problem is to select in which direction the manouevre should be performed. In fact in general an accurate missile position is not available and to provide the Defence System of the platform with the capability of measuring the missile position could means an higher system cost and complexity. Not to mention the fact that, in the presence of the multiple attacks, the manoeuvre could not be convenient at all.

- Multiple attacks: in the presence of multiple attacks, there is the possibility that the Towed Decoy, which by its very nature try to attract missiles, could be destroyed by a missile. Consequently the platform remains without electronic defence to be used against a subsequent missile.

- Life cycle cost: considering that in a fighter aircraft , in order to save weight and space, it is better to avoid a winch to recover the decoy, the towed decoys become expendable. Consequently, the life cycle-cost of this technique becomes very high. Probably, from this point of view, the Towed Decoy technique could be convenient only to protect wide body aircraft, where it is possible to install a decoy recovery winch.

Expendable Decoy

Airborne Platforms. In the case of Airborne platforms, expendable decoys are very small flying objects normally ejected by chaff/flare dispenser, capable of radiating decoying signals.

Since they are very small, their power is generally adequate to counter only CW or low ERP radars and they are generally tailored against specific threats.

Advantages.

The advantage of airborne expendable decoys is represented by their relatively low cost and by the fact that a platform can store several expendables to counter many attacks.

Disadvantages.

Airborne Decoys are presently dedicated to some specific threats and are not general and generic.

Naval Platforms. In the case of Naval platforms, expendable decoys are relatively "small" flying objects (some time floating in the sea) with a decoying system capable of repeating the radar signal in such a way as to simulate a ship skin echo (see Fig. 6).

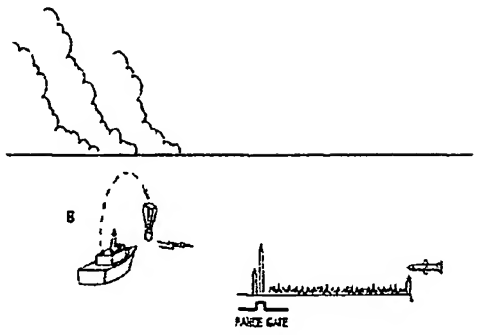

Fig. 6: Naval expendable

The decoy payload can radiate an ERP adequate to seduce radar/seeker range gates.

Advantages.

Naval expendables have a moderate cost and can be effective against all expected seekers.

Disadvantages.

- Settling time: the expendable must be launched after detection of an incoming threat. It requires a certain period (several seconds) before the expendable can be operational in the right position. The settling time can be too long against seekers that switch on at very short ranges.
- Credibility: anti ship missiles can be equipped with a seeker capable of discriminating between false and real targets. Therefore to be effective a naval expendable decoy must be able to simulate, in great detail, the ship skin echo return. This implies a significant complexity and make the expendable quite expensive.
- Availability time: flying, gliding or even parachuted expendables can be operational for a limited time, due to various reasons: TWT temperature, electrical power, dropping speed, etc.
  Floating expendables can be operational for a longer time, but they cannot be always effective if the sea is not calm.
- Position: parachuted or gliding expendables

position could result inadequate in the presence of a strong wind, if the wind is blowing in the wrong direction with respect to the ship course. Moreover, in presence of multiple attacks a position suitable to counter one missile may not be convenient at all to counter other missiles.

- Multithreats: in the presence of multiple attacks, there is the possibility that the Expendable Decoy, which by its very nature tries to attract missiles, could be destroyed by a missile. Consequently the platform remains without electronic defence to be used against a subsequent missile.
- Storage (Munitions): due to the long durations of ship missions, the number of dangerous situations (and consequent false alarm possibility that can cause expendable launch) are quite high: therefore the number of expendables to be store a on board could be quite high.

  Consequently the life cycle cost of the expendable jamming technique can be very high.

Cross-Eye Jamming

This ECM technique requires a double antenna-transmitter and relevant circuits in order to be able to generate two signal replicas that have to be received by the victim radar out of phase and with a certain amplitude unbalance.
These two signals try to create in the radar a situation similar to that known as "multipath" to radar experts (see Fig. 7)

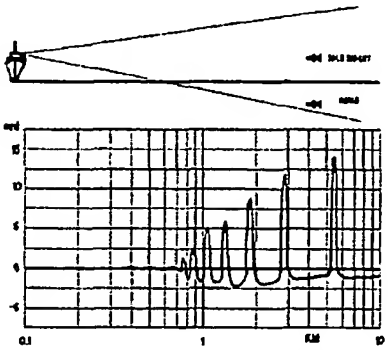

Fig. 7: Multipath effect

This situation occurs to a radar when it is tracking a target at low heights. In this case the radar receives two signals: one is the direct one, the other is that reflected by the sea surface.
The laws of physics demonstrate that when the two signals are received by the radar out of phase and with a certain amplitude unbalance, the radar aiming point is far away from the real target position along the line passing through the real target and the image target, in the direction of the stronger signal (see Fig. 8).

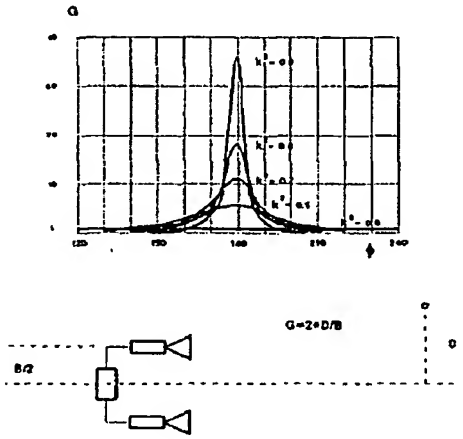

Fig. 8: C.E.J. technique characteristics

In fact, in this condition what happens is the well known "wave-front distortion" (WDF) effect and since tracking radars aim in a direction which is orthogonal to the received wave-front, a large aiming error is so created.
Jamming exploiting wave-front distortion causes a displacement of the tracking radar aiming point towards the direction of the stronger jamming signal.
It is also possible to demonstrate that the effect of this technique is like a displacement of the real target to a new position. This displacement is, in the ranges of interest, practically independent from the distance, and therefore it is possible to achieve a significant miss-distance also against missiles in their terminal course.
If very fast signal processing is used and if a proper dimension for the WFD base is chosen it is possible to generate the jamming signals in such

a way that they arrive at the radar receiver inside the target skin echo.
In this condition the victim radar can not discriminate between echo and jamming signals: the radar will see only one target to track that is far away fron the real one.
In other words, the Cross-Eye jamming technique will create, for the victim radar, a "virtual Off-Board Decoy" which will drive the terminal weapon far away from the real target.

Advantages

The advantages of the Cross-Eye jamming technique are:

- High effectiveness against all expected threats;
- Multithreats capability;
- Impossiblity to discriminate real/false targets;
- Unlimited availability.

Disadvantages.

To implement WFD jamming technique a very advanced technology is necessary to ensure amplitude and phase matching of two receiving-transmitting paths and to ensure a "super" fast signal processing.
Moreover to be effective against semi active missile, some additional circuitry may be required.
Since the technique requires two antenna - transmitters to cover an angular sector of 120°, EW systems based on WFD are more expensive than traditional EW systems.
When it is required to provide a coverage of 360° (naval case) more double antenna-transmitters (minimum 3) are necessary and consequently some installation problems could arise if the right cost/effective solution is not chosen.

CONCLUSION.

From the above considerations, it appears that, among the various anti-monopulse jamming techniques analysed, the Cross-Eye Jamming appears to be the one capable of providing the best effective protection.
Now that in Italy it has been demonstrated that the Cross-Eye Jamming can be conveniently implemented by exploiting already available technologies and that the predicted performances can be really achieved, it is expected that in the near future many new jamming systems will be based on the Cross-Eye Jamming technique.